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NOLTR 63-43

TRANSISTOR WATER ENTR / SHOCK
RESISTANCE SURVEY FOR RUGGEDIZED
SONOBUOY

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26 FEBRUARY 1963

UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

NOLTR 63-43

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**TRANSISTOR WATER ENTRY SHOCK RESISTANCE SURVEY
FOR RUGGEDIZED SONOBUOY**

**Prepared by
Ralph E. Tabler
Environment Simulation Division**

ABSTRACT: Transistor types 2N169A, 2N220, 2N200, and 2N741 were tested for their resistance to water-entry shock. A total of 147 transistors was mounted in one of three ways: (1) polyethylene holder and potted in polyethylene, (2) polyethylene holder and potted in Dow-Corning 601, and (3) potted in Dow-Corning 601 alone. The polyethylene holder and the 601 potting proved to be the most shock resistant mounting method. All of the transistors proved to be sufficiently rugged to survive the water-entry shock expected in service use of the NOL free fall miniature SONOBUOY.

PUBLISHED APRIL 1965

**U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND**

Change 1

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R. E. ODENING
Captain, USN
Commander

V. M. KORTY
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REFERENCE

(a) NOLR 1056, "Shock Testing Facilities"

INTRODUCTION

1. The Naval Ordnance Laboratory is engaged actively in developing a ruggedized free-fall miniature SONOBUOY. Because the SONOBUOY is basically a hydrophone, amplifier, and transmitter, rugged electrical components are absolutely necessary for a reliable free-fall buoy. The Laboratory has accumulated considerable data and experience in ruggedization and miniaturization techniques from previous tasks such as VT Fuzes. From these tasks information on the ruggedness and mounting methods of resistors, capacitors, coils and miniature vacuum tubes is available. However, little information of this type is available on transistors. Because all the circuitry as presently conceived in the SONOBUOY(NOL) is transistorized, it was felt that mounting and ruggedness data were needed for transistors. A test program was planned not only to be useful to the SONOBUOY development program, but also for future ordnance ruggedization programs.

WATER ENTRY

2. Because the free-fall buoy enters the water at velocities as high as 350 knots, it can experience high deceleration forces at the air-sea interface. The water-entry shock occurs in two phases. The first or impact phase is the initial momentum exchange between the water and the entering body. This shock is of a short duration and a high acceleration. For the NOL buoy it is on the order of 0.15 to 0.25 millisecond in duration and 4,000 to 5,000 g in peak. In terms of velocity changes, this is from 10 to 20 feet per second. The second, or drag phase, is due to the viscous forces after the underwater flow pattern has developed. This acceleration is of the order of 400 to 800 g peak and 15 to 25 milliseconds duration.

3. To simulate water-entry shock, NOL has developed captive air guns using special two-phase pistons. The air gun is basically a long closed tube (58 feet for the 15-inch gun) with a piston containing the test specimen at one end. A mechanical latch releases the piston on command and the piston with the test specimen is accelerated down the tube. Because the tube is closed off, the pressure builds up at the other end and decelerates the piston. After several oscillations in the tube, friction finally brings the piston to rest. At this time the muzzle end of the door is opened and the piston and specimen are removed from the gun. In order to simulate the two-phase water-entry shock, the piston is equipped with a movable carriage and an anvil. The carriage holding the test specimen is set a fraction of an inch from

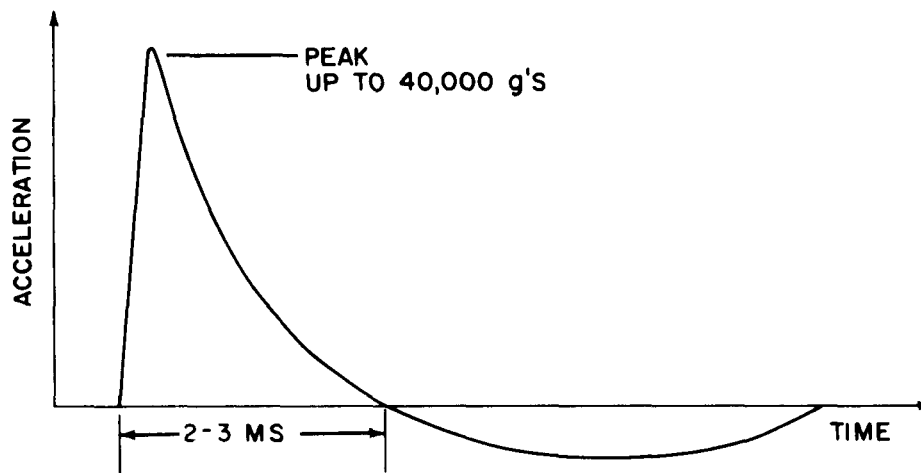
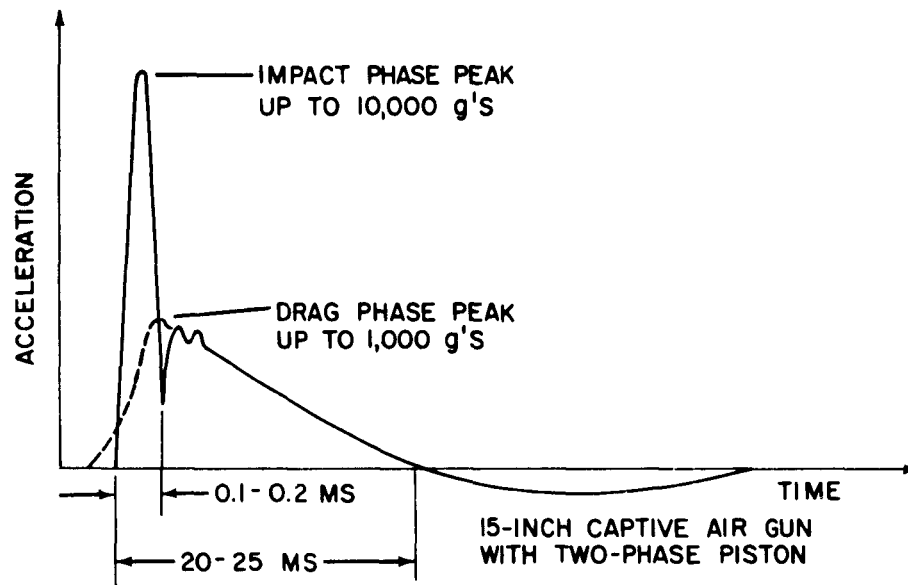


FIG. 1 5" HI-G AIR-GUN
IDEALIZED ACCELERATION-TIME
CURVES OF NOL CAPTIVE AIR-GUNS

the anvil by adjustable guides and held in place by springs. Upon release of the piston, the carriage immediately strikes the anvil and is held there by spring loaded fingers. This results in a steel-on-steel impact of high acceleration for a short duration similar to the first phase of water entry. The drag is simulated by the acceleration of the piston as it continues down the tube. The top curve of figure 1 is an idealized acceleration-time curve produced in the NOL 15-inch Air Gun using a two-phase piston. The bottom curve is an idealized acceleration-time curve produced using a single phase piston in the NOL 5-inch Hi-G Air Gun. By use of the NOL 5-inch Hi-G Air Gun impact phase pulses greater than 10,000 g can be simulated. More details on the air guns and water-entry simulation are given in reference (a).

TEST PROCEDURE

4. To test the transistors for ruggedness, seven levels of shock were chosen. The first three levels were obtained in the 15-inch Air Gun. In order to go to higher shock levels, it was necessary to use the 5-inch Hi-G Air Gun. This gun uses only single phase pistons; thus the last four levels are single phase shocks. Because the potted transistor is small and rigid, it is more responsive to high frequency shocks. The short duration impact shock excites these systems and their response is altered by the second or drag phase shock in the NOL 15-inch Air Gun using a two-phase piston in a manner thought to simulate water entry shock. The short rise time (less than .1 millisecond) high magnitude NOL 5-inch Hi-G Air Gun single phase pulse also excites these rigid systems and the sustained acceleration alters their response in much the same manner as true water-entry shock. Hence, the shift in simulation technique from two-phase to single-phase at shock level 4 is considered logical as well as practical. The following are the shock levels used:

- Level 1 - 20 feet per second velocity change impact phase with a 450 g peak drag phase
- Level 2 - 25 feet per second velocity change impact phase with a 500 g peak drag phase
- Level 3 - 30 feet per second velocity change impact phase with an 800 g peak drag phase
- Level 4 - 10,000 g peak
- Level 5 - 15,000 g peak

Level 6 - 20,000 g peak

Level 7 - 25,000 g peak

In the first three shock levels, the impact phase is given in terms of velocity change because the instrumentation to determine this in the air gun is much simpler than that required for acceleration. In the remainder of this report when reference is made to a shock level, it will be defined as above.

5. Normally in circuit design, one tries to obtain commercial components that meet the necessary electrical and environmental requirements. If there are shock limitations in the component, it is often possible to mount or support them in such a manner to meet the requirements at hand. After studying the electrical and mechanical characteristics of various potting compounds to determine if they meet the SONOBUOY environmental requirements, three methods for mounting the transistors for the NOL SONOBUOY were considered. It was decided to incorporate all three of these different mounting methods in the transistor shock test to obtain more data to aid in a final selection.

6. In the three potting methods, only two compounds were used: Dow Corning 601, which is a room temperature vulcanizing mixture, and low density polyethylene which is inserted around the components at 50 psi and 320°F. By making component holders from solid high density polyethylene stock and potting either the 601 or the low density polyethylene around them, two methods of mounting the transistors were effected. The third was to pot the transistors in the 601 without the holder. This can be done conveniently because of the room temperature characteristics of the Dow Corning 601.

7. The transistors were potted in available fuze containers. They were mounted in the polyethylene holders and wired to the base of the fuze can. Figure 2 shows the orientation and wiring of the transistors without the holder and the can removed. The reason for the different orientations was to determine if the transistors had a directional shock sensitivity. After they were mounted and wired in the can, they were potted in one of the three aforementioned ways. Figure 3 shows the potted units with the outer can removed.

8. When referring to the direction the transistor was shocked, the numbers associated with the arrows in figure 4 will be used. These illustrations of the internal structure give the direction of the shock (applied acceleration) with

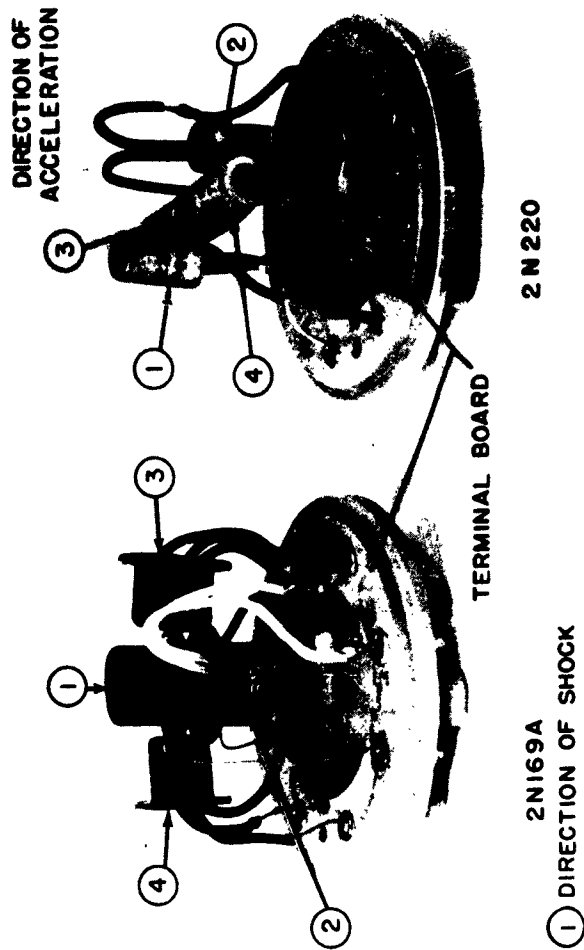


FIG. 2 ORIENTATION AND WIRING

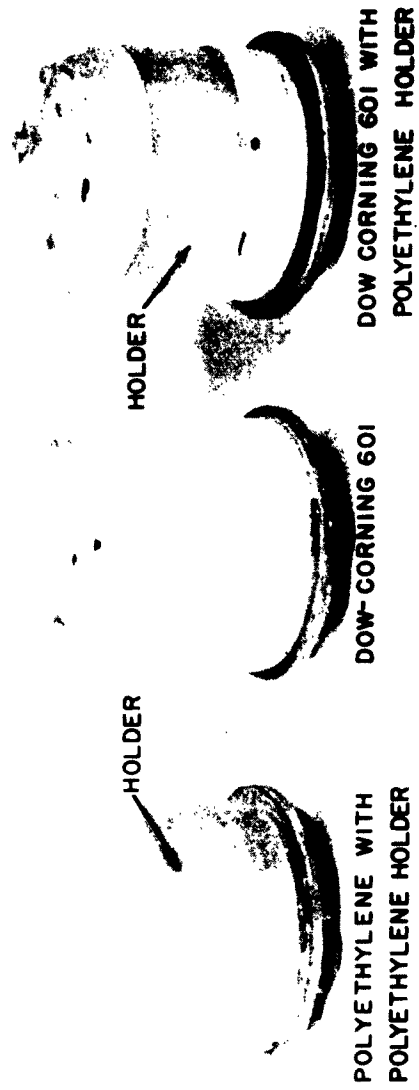


FIG. 3 POTTING METHODS

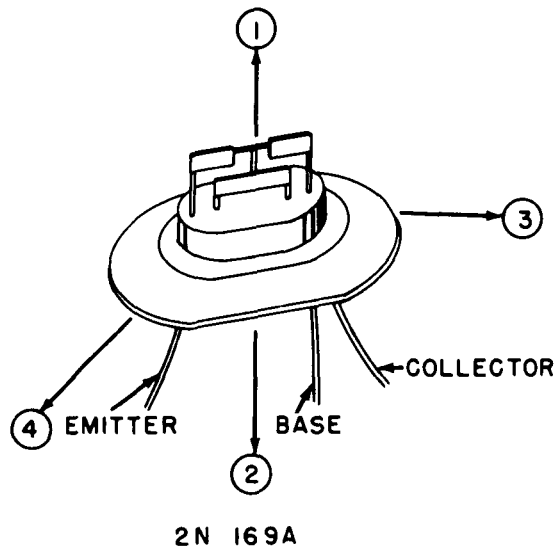
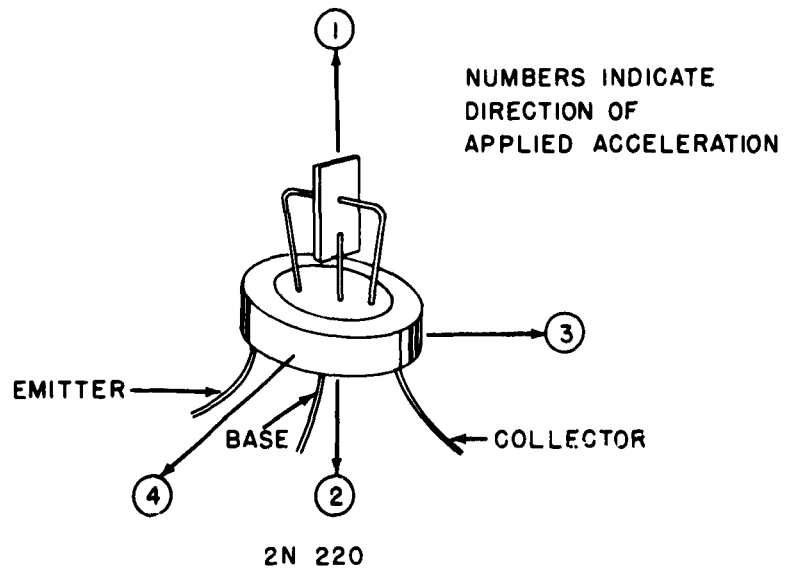


FIG. 4 TRANSISTORS (CASE REMOVED)

respect to the transistor's construction. They also give some ideas of how mechanical failure could occur with different directions in the two transistors shown.

9. Two factors were considered in the selection of the transistors to be tested: (1) their possible use in the SONOBUOY circuits, and (2) their availability from stock at NOL. Using these criteria, the following transistors were selected: 2N741, 2N700, 2N220 and 2N169A. Because the latter two were more plentiful, they were the most used in the program. These types do not cover all the transistor functions required in the SONOBUOY circuit. Other transistors were tested but their numbers were too small to obtain sufficient data for concrete conclusions.

10. The following tables give the way in which the transistors were divided as to direction, potting method, and type:

TABLE 1. POLYETHYLENE HOLDER WITH POLYETHYLENE POTTING
DIRECTION OF ACCELERATION VS SAMPLE SIZE

<u>Direction</u>	<u>2N169A</u>	<u>2N220</u>	<u>2N700</u>	<u>2N741</u>
1	5	5	3	2
2	5	5	3	2
3	5	5	3	2
4	<u>2</u>	<u>2</u>	<u>0</u>	<u>0</u>
Total Sample	17	17	9	6

TABLE 2. POLYETHYLENE HOLDER WITH DOW CORNING 601 POTTING
DIRECTION OF ACCELERATION VS SAMPLE SIZE

<u>Direction</u>	<u>2N169A</u>	<u>2N220</u>	<u>2N700</u>	<u>2N741</u>
1	5	5	3	2
2	5	5	3	2
3	5	5	3	2
4	<u>2</u>	<u>2</u>	<u>0</u>	<u>0</u>
Total Sample	17	17	9	6

TABLE 3. DOW CORNING 601 POTTING ONLY (NO HOLDER)
DIRECTION OF ACCELERATION VS SAMPLE SIZE

<u>Direction</u>	<u>2N169A</u>	<u>2N220</u>
1	2	2
2	2	2
3	2	2
4	<u>2</u>	<u>2</u>
Total Sample	8	8

This is a total sample of 114 transistors: 42, 2N169A; 42, 2N220; 18, 2N700; and 12, 2N741.

EVALUATION OF FAILURES

11. Because the SONOBUOY is not turned on until after water entry, the transistors are nonoperating during the shock. Thus, to determine the effect of the test, each transistor was checked prior to the shock series and after each shock. The transistors were not monitored during the shock tests. The checks were made using a Tektronix Model 575 curve tracer for the collector current and collector voltage family of curves. Significant deviation from the original curves was classified as failure. If there was insignificant change, the transistor was then subjected to the next shock level until the series of seven shocks was completed. Repeated shocks on the transistor could progressively weaken their shock resistance, but the number of transistors required to test unshocked samples each time was unreasonable for the information desired.

12. When a failure was detected by the curve tracer, the transistor was X-rayed in an effort to determine if it was an open circuit or short circuit type of failure. Further examination included removal of the case and a visual inspection. In general, this type of failure was not investigated too thoroughly because it was felt that the fact that it failed at a certain shock level was far more important than how it failed. This approach was taken because this was an "off-the-shelf" transistor ruggedness test program and not a design program.

TEST RESULTS

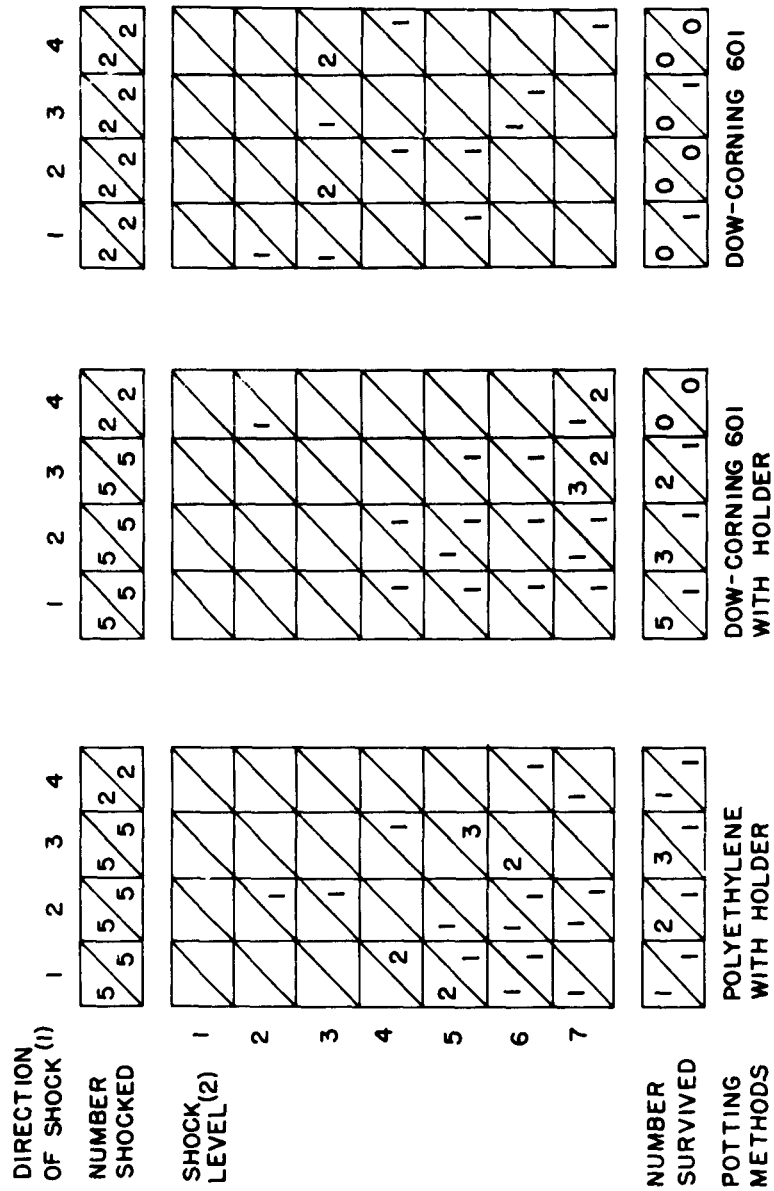
13. After completing the seven shock levels, there was only one 2N700 and one 2N741 that failed. Both failures were at the level seven shock. Because only two failed, no significant conclusion could be drawn about directional sensitivity or potting methods for these two transistor types. The important thing, however, is the fact that they withstood such high shock. Both types are high frequency transistors, small and light compared to the other two types tested. It is felt that this small size is the major factor accounting for their high shock resistance.

14. Since there were several failures in the 2N169A and the 2N220 samples, a few conclusions may be drawn from the results. Figure 5 is a table of the failures and the levels at which they occurred. Seventy-nine percent of the 2N220's and sixty percent of the 2N169A's had failed after the seventh shock level. All the failures were mechanical. Either the semiconductor junction cracked and separated, or there was a short due to a permanent displacement of the elements. Approximately 60% of the failures were open circuits and the remaining 40% were shorts.

CONCLUSIONS

15. Figure 6 is a combined plot of the 2N220 and 2N169A failures versus potting and shock levels. It can be seen that a higher percentage of the failures occurs in the 601 alone at lower levels. The best potting method seems to be the polyethylene holder potted in Dow Corning 601. This type of potting creates a low frequency mounting system because the holder acts as a large rigid mass and the 601 acts as a very soft spring. This type of mount sees little of the high rise time shock of short duration.

16. There were no failures at the first shock level. This shock is slightly in excess of what is expected for the (NOL) SONOBUOY. Thus, all the transistors and mounting methods tested would be satisfactory for application in the buoy. But if improved shock resistance characteristics are necessary, this program has demonstrated that the smaller transistors are more shock resistant and that the polyethylene holder potted in Dow Corning 601 is the best mounting method of those tested.

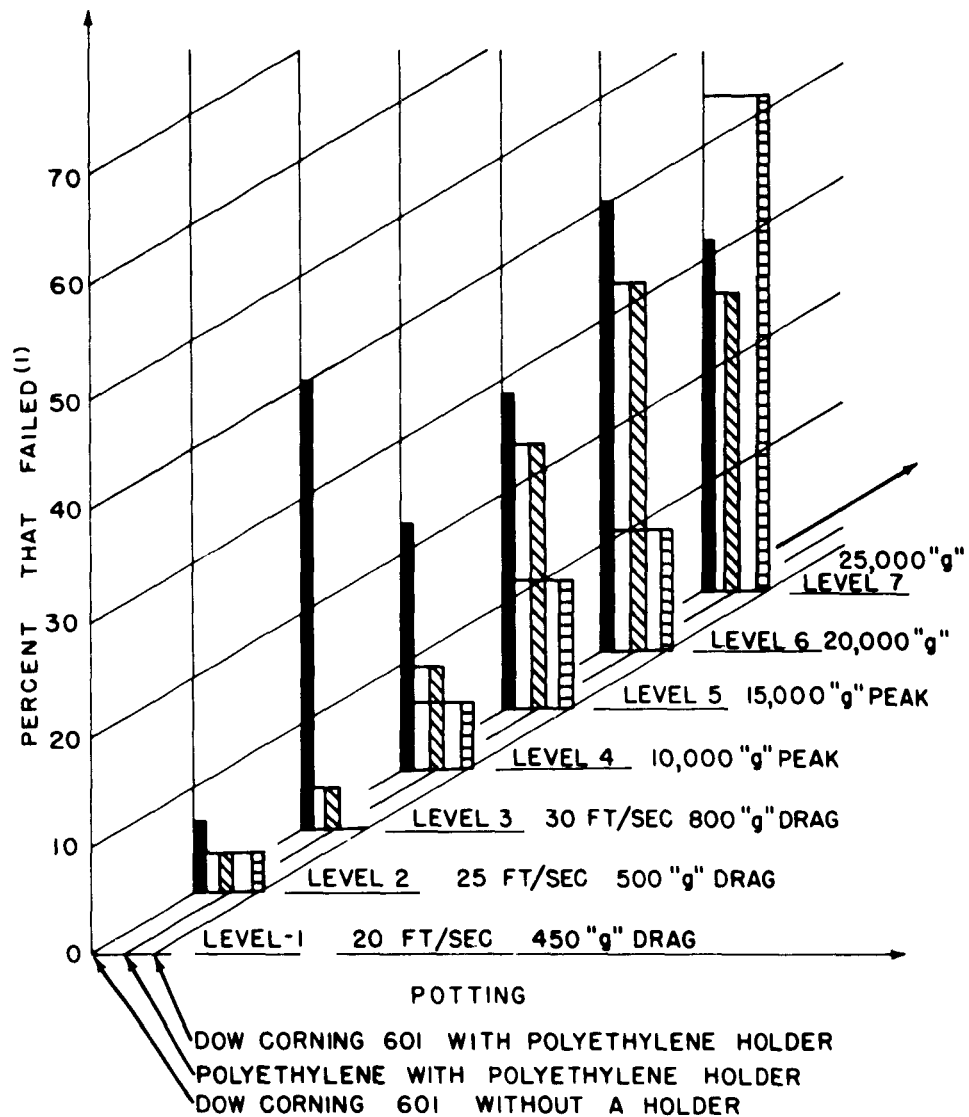


KEY: 2N169A 2N220 THE NUMBER OF FAILURES AT THAT SHOCK LEVEL DIRECTION

NOTE: (1) THE DIRECTION OF THE SHOCK IS AS DEFINED BY FIG. 4

(2) THE SHOCK LEVELS ARE DEFINED ON PAGE 3-4

FIG. 5 LIST OF FAILURES VS POTTING AND SHOCK LEVEL



NOTE (i) THE NUMBER SHOCKED AT EACH LEVEL DIFFERS BY THE NUMBER THAT FAILED AT THE PREVIOUS LEVEL. THIS IS THE COMBINED FAILURES OF THE 2N169A AND THE 2N220.

FIG.6 FAILURES VS POTTING AND SHOCK LEVEL

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